Results of the Tests of a CMS Tracker Inner Barrel Sub-structure with a 25 ns Beam

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Abstract

A beam test was performed in May 2003 to validate with an LHC-like beam all the CMS Tracker final components assembled together, including detectors, mechanical structure, fully optical readout, DAQ, power supplies and cables and to test the stability of the overall system. A sector of the third layer cylinder mechanical support was produced according to the final design and was equipped with services. Six modules from a pre-production and their corresponding optical hybrids were also installed in this sub-structure. This system was brought to CERN X5 beam area and connected to the power supplies and DAQ. After a relatively short period of commissioning, the system worked successfully and a very large number of events was taken. Data were carefully analysed and several results about charge collection, noise, detector performance under different bias voltage, time structure of the signal, and detector uniformity were obtained from these studies. The main system aspects as well as the DAQ and experimental setup are described and the main results about detector performance are discussed.

I. Introduction

The CMS Tracker [1][2] will be the first tracking system completely based on silicon detectors. Tracker modules will be installed in cylindrical layers in the central region and disks in each forward region, for a total active area of $\sim 200\ \mathrm{m}^2$. With the exception of the innermost part which will be instrumented with pixel detectors, the rest of the Tracker will be made out of silicon microstrip detectors with different geometries according to their distance from the beam axis [3]. The Tracker is divided if four regions: Inner Barrel (TIB), Inner Disks (TID), Outer Barrel (TOB), End Caps (TEC).
Detectors and mechanical structures, power supply units and all elements of the readout chain have been extensively tested and characterized so far in many test centers. For the first time the final components were assembled together and the overall system was tested in with a 25 ns bunch spacing and the huge amount of data taken provided a realistic study of detector performance.

II. System Aspects, Test Setup and DAQ

A sector of the third CMS TIB layer half-shell was assembled according to the final design of the corresponding cylinder. This structure was equipped with four strings, each string consisting on one mother cable, a Communication and Control Unit (CCU25)[4] chip and one cooling loop with mechanical supports for modules and Analog Opto-Hybrids (AOH) [5]. Six modules of a pre-production and the corresponding optical hybrids were grouped in two groups of three and each group was installed one of the two central strings. These modules consist of a single-side Hamamatsu sensor of 300 μm thickness, with 512 strips 120 μm pitch connected to a hybrid with four APV25 chips [6].
The sub-structure was mounted on a mechanical support so that the surface of one the central strings could lay vertically and the system was placed at the CERN X5 facility. A picture of the TIB sub-structure in the beam test area is shown in Fig. 1.

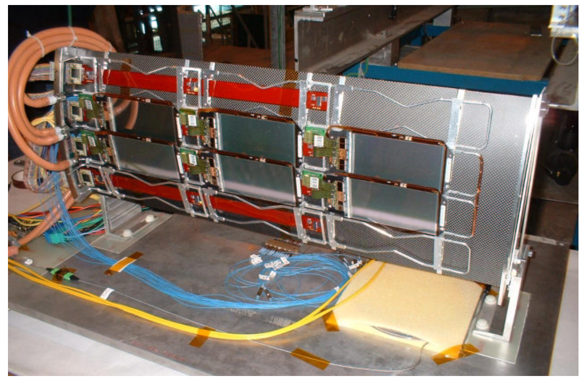

Figure 1: TIB sub-structure at the CERN X5 beam test facility.

Modules were powered up with two different prototypes of the final power supply units (from CAEN and LABEN) placed inside the control room and providing both low than high voltage through a 125 m long low inductance power cable of the final type. The readout and control was performed through PCI mezzanine boards (PMC) placed in the control room, very similar to the corresponding final VMEbus FED and FEC boards. Data and Control signals were transmitted to the Counting Room through the final optical fibres.
In the same beam test a box with six TOB modules was placed downstream the TIB sub-structure and red out with a fully optical read-out system.
For the first time it was possible to test a DAQ software very similar to the final CMS DAQ software. Automated procedures allowed the commissioning of the system. The three systems were operated independently in a first stage and in a second stage the TIB and TOB DAQ systems were merged together and red out coherently as if they were a single detector, demonstrating the scalability and the commission capability of the software.
The Trigger was provided by the coincidence of 2 plastic scintillators. The position of the TIB sub-structure was optimized in order to spot a region between the central detectors of the instrumented strings. Both 120 GeV/c momentum pions and muons were available during tests. The beam had a LHC-like structure with 3 ns long bunches spaced by 25 ns. Pion beams provided up to 2500 events per spill, while the intensity of muon beams was 10 times smaller.

III. Operation and Detector Performance

The test beam lasted from May 12 to June 4, 2003. After two days of system commissioning, the running was stable throughout all the period and several thousands events were collected in several running conditions. Offline reconstruction was performed with a three thresholds cluster finding algorithm.

The modules performance was studied in detail: for every run the cluster charge (S) and cluster noise (N) were extracted from a Landau and Gaussian fit of the charge and noise associated to collected clusters and results are in agreement with predictions. Cluster width, cluster shape and correlation function were also studied in detail for different running conditions.

Module performance was also investigated for TIB and TOB modules under different bias voltage: modules were operated well above full depletion and showed a stable behaviour. As an example the Signal to noise ratio for TIB modules in deconvolution mode is shown in Fig. 2 as a function of the bias voltage (the nominal depletion voltage is around 150 V) and the asyntotic value $\sim$ 18 is in agreement with the predicted one.

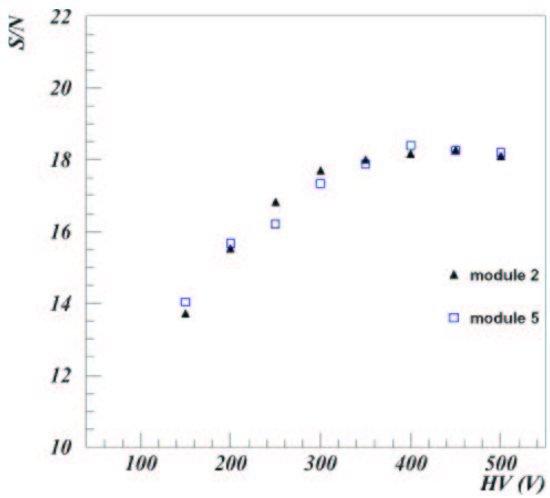

Figure 2: Signal to noise ratio for TIB modules in deconvolution mode as a function op the bias voltage.

The shape of the signal was studied performing a PLL fine delay scan in both peak and deconvolution APV modes. The signal shape in peak mode, shown in Fig. 3, is agreement with the one expected from a CR-RC pulse shaping with a typical rise time around 55 ns. The shape in deconvolution mode is symmetric and the rise time is around 25 ns, which should allow a correct bunch crossing identification in the high luminosity phase of LHC. The time structure of the signal was studied for the charge collected by the overall cluster, the cluster seed and the neighbouring strips.

Very High statistics runs were also taken to investigate the uniformity of TIB and TOB detectors. Cluster charge, noise S/N ratio and cluster width were computed in small intervals of the length of the detector pitch and centered at each strip. Values associates to different channels were then compared. These variables are uniform within 1-2% within portions of the detectors red-out by the same chip. Since strips of TIB modules are perpendicular to those of TOB modules, it was also possible to extract the hit position along the strips of a TIB modules using informations coming from TOB ones. Therefore, it was possible to study the uniformity of TIB along the strip for the same variables. The result of this analysis was that charge and S/N ratio are again uniform within 1-2%.

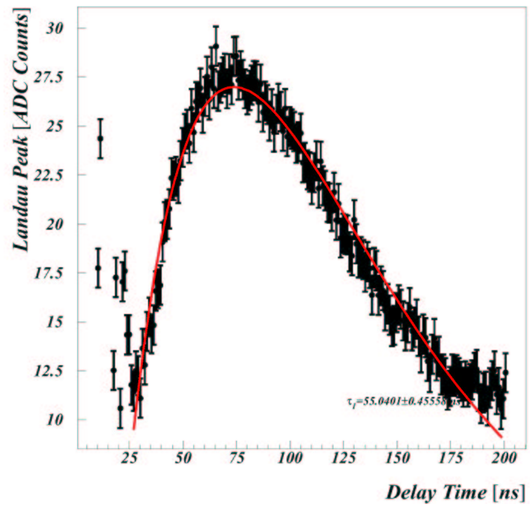

Figure 3: Collected charge as a function of the PLL delay time for a TIB module in peak mode.

IV. Conclusions

For the first time it was possible to perform a TIB system test with 25 ns beams: the whole system and all single components showed a stable operation and demonstrated their capability to work with the LHC rates with a very good performance. The success of this test encouraged the start-up of mass production of all Tracker elements, the integration of components on the final mechanical structures, tests on more complex systems and further studies on detector performance before the final Tracker installation.

V. References

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